IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

COAL: A VITAL ENERGY RESOURCE UNDER SCRUTINY

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Abstract

In 2022, global coal demand surged to an unprecedented 8.42 billion tonnes (Bt), marking a 4% increase from the previous year, driven primarily by Asia. China witnessed a 4.6% rise, equivalent to 200 million tonnes (Mt), while India and Indonesia experienced hikes of 9% (97 Mt) and 32% (49 Mt) respectively, with nickel smelters notably contributing to Indonesia's growth. Conversely, the United States observed an 8% decline, amounting to 37 Mt, the most significant drop globally, while Europe's 4.3% consumption uptick was subdued due to factors like a tepid economy and mild winter. Although some European countries faced subdued hydropower and nuclear electricity generation, natural gas price spikes prompted a shift to coal. However, in 2023, advanced economies, particularly the European Union and the United States, are anticipated to witness substantial declines, approximately 20% annually. Nonetheless, China and India, with growth rates of approximately 5% and 8% respectively, alongside Indonesia, Vietnam, and the Philippines, are projected to offset these decreases, collectively accounting for over 70% of global coal demand. Despite commitments to renewable energy, emerging economies like India and Indonesia are expected to rely on coal to sustain robust economic expansion, leading to a slight 1.4% growth in global coal demand to a new high of 8.54 Bt in 2023. Notably, China's dominance in the coal market surpasses that of any other country for any fuel, consuming and producing more than half of the world's coal while serving as the largest importer, controlling nearly one-third of the global coal trade.Top of Form

***Keywords**: Coal demand, Carbon emissions, Renewable energy*

I. Introduction

Coal, a fossil fuel, forms from plant remnants undergoing intense heat and pressure over millions of years. This 'coalification' process creates dense, carbon-rich seams within rock layers. When burned, coal releases ancient solar energy stored by plants. There are four main types of coal: lignite, sub-bituminous, bituminous, and anthracite. Their quality depends on factors like vegetation type, burial depth, and time. High-rank coals have high carbon content but burn slowly, while low-rank coals have less carbon but burn faster. Despite this, low-rank coals are still used in modern applications, with some of the most efficient power plants relying on them. Local power plants near coal mines, termed mine-mouth plants, operate on local coal sources. These plants have a straightforward coal value chain, resulting in low generation costs. While substituting local coal isn't always easy, blending with foreign coal may be an option. Power plants located farther from coal mines must meet specific performance standards based on internationally traded coals. Achieving these standards often involves blending different coal types from various countries to ensure both performance and quality requirements are met. Coal remains crucial in the energy supply of over 80 countries, not only for electricity but also for heat production. According to the International Energy Agency (IEA), it is projected to remain the world's largest single source of electricity by 2040. In many regions, coal-fired district heating systems provide residential heating during colder months. Moreover, coal supports agriculture in two significant ways: by producing ammonia through gasification for use as a nitrogen source in fertilizers, and by extracting humates from coal to supplement soils, especially in Asia where demand for humic products is rising annually by 10 per cent. These practices help mitigate food scarcity, cut costs, reduce waste and pollution, and support food production. Coal and coal waste are rich sources of critical heavy metals essential in various applications. Burning coal produces valuable coal ash that reduces the climate impact of cement production. Additionally, coal ash and coal sludge contain thousands of tonnes of essential heavy metals crucial for manufacturing steel, cement, and aluminium. Coal plays a vital role in manufacturing wind turbines, especially in China, a global leader in coal production. Each turbine requires significant amounts of coking coal and iron ore for steel production. (***https://www.futurecoal.org/coal-facts/***)

Coal, described as the "largest source of solid fuel in the world" **(Miller, 2011a)**, sparked a transformative era: as populations expanded and biomass resources diminished, coal played a pivotal role in the advancement of general manufacturing, iron and steel production, power generation (including steam power), railways, and various other industries **(Fouquet and Pearson, 1998;**

Kennedy, 2020). Often personified as "Old King Coal" **(Mackay, 1859; Mathis, 2018)**, this seemingly ordinary, combustible substance, often likened to "black stuff that arrives mysteriously from nowhere" **(Orwell, 1937)**, served as the primary source of heat, steam, and electricity for decades, enabling humanity to reshape nature's harsh environment into a more hospitable and civilized world **(Freese, 2003)**.

Table 1 – Coal Reserves in Selected Countries of the World

Country	Coal Reserves (Mega Tonnes)	Share % of Global Total
United States	248,941	23.2
Australia	150,227	14.0
China	143,197	13.3
India	111,052	10.3
Germany	35,900	3.3
Indonesia	34,869	3.2
Ukraine	34,375	3.2
Poland	28,395	2.6
Kazakhstan	25,605	2.4
Turkey	11,525	1.1

Source*: https://worldpopulationreview.com/country-rankings/coal-reserves-by-country*
Note*: A megatonne (Mt) is a unit of mass equal to one million metric tons, or 1,000,000,000 kilograms. It is commonly used to measure large quantities of mass, particularly in contexts such as environmental impact assessments, industrial production, and resource extraction.*

As indicated in Table 1, North America's coal reserves are predominantly held by the United States, accounting for approximately 23.2 per cent of the region's total by the end of 2020. Mexico and Canada, in contrast, possess less than one per cent each of the total supply. Despite this, they could potentially reduce their reliance on natural gas or petroleum fuel, especially in light of the Ukraine War. In South and Central America, including countries like Brazil, Colombia, and Venezuela, the combined coal supply represents only 1.3 per cent of the world's total. Brazil holds the largest share within the region, yet it remains less than one per cent. Although Brazil may struggle without natural gas, certain areas of the continent already face challenges with consistent utility power. Approximately 12.8 per cent of the world's coal reserves are distributed among a dozen countries and others not specified. Ukraine boasts the highest share at 3.2 per cent, followed by Turkey at 1.1 per cent. However, countries like Bulgaria, the Czech Republic, Germany, Greece, Hungary, Poland, Romania, Serbia, and Spain have less than one per cent of the supply or just a fraction thereof. The topic of increased coal demand has emerged globally, partly due to the Ukraine war and the ongoing natural gas shortages since 2020 extending into 2022. The Commonwealth of Independent States (CIS), comprising several former Soviet states, holds significant coal reserves, with the Russian Federation alone possessing 15.1 per cent of the region's total. Kazakhstan contributes 2.4 per cent, making up a combined 17.8 per cent of global coal ownership. In the Middle East and Africa, countries like Zimbabwe, South Africa, and most Middle Eastern nations hold only 1.5 per cent of the world's coal reserve. Despite this, some Middle Eastern countries, including Turkey, Egypt, Israel, Jordan, Syria, Iran, the United Arab Emirates, Oman, and Pakistan, have initiated plans to construct coal plants, with construction underway in certain areas since 2018. Global coal demand continues to rise as natural gas prices soar and shortages persist into 2022. The Middle East and Africa region collectively possess 42.8 per cent of the world's total coal supply, with Oceanic countries like Australia contributing significantly with 14.0 per cent. However, New Zealand's share remains below 1 per cent. China holds 13.3 per cent of the world's coal reserve, followed by India at 10.3 per cent and Indonesia at 3.2 per cent. Other countries such as Japan, Mongolia, Pakistan, South Korea, Thailand, Vietnam, and others not listed each possess less than 1 per cent of the world's total coal reserve.

II. Some Studies on Coal

According to **James et al. (2005)**, coal constitutes approximately 30 per cent of global fossil fuel consumption and contributes to 37 per cent of carbon dioxide emissions from fossil fuels. Its primary usage is in the electric power sector, where it accounts for over half of the primary energy input. With its abundance, coal's usage for electricity generation is anticipated to increase throughout this century, particularly in the absence of penalties or restrictions on carbon dioxide emissions. Nevertheless, policies aimed at curbing carbon dioxide emissions have the potential to challenge coal's dominance in favour of the less carbon-intensive natural gas. Carbon dioxide capture and storage (CCS) technologies offer a promising solution to mitigate this transition. To analyze the implications of these dynamics in a carbon-constrained environment, the study examines four factors influencing future coal consumption in the electric power sector: the price of carbon emissions, the price of natural gas, costs associated with CCS technologies, and the dispatch between coal and natural gas generation technologies. Plausible yet diverse scenarios are developed for these variables, and their impact on coal consumption is evaluated using the MIT Emissions Prediction and Policy Analysis (EPPA) model, a computable general equilibrium model of the world economy. The findings reveal how competing technologies, shifts in input prices, and general equilibrium effects shape the adoption of CCS technologies. Notably, the results for the United States and Europe indicate that carbon pricing and dispatch play a significant role in determining future coal consumption. While advancements in CCS technology costs lessen coal consumption's dependence on gas prices, they do not alleviate the impact of carbon pricing on consumption through 2050.

Miller (2005) delves into the historical, contemporary, and prospective roles of coal, offering insights into its utilization compared to alternative energy sources. While the focus primarily rests on coal usage within the United States, the narrative extends globally, especially in terms of juxtaposing overall energy consumption patterns. The chapter also highlights the technological advancements dating back to the Industrial Revolution. Although coal has served as an energy source since ancient times, its significance remained marginal until the Industrial Revolution. The earliest documented use of coal is attributed to Aristotle's Meteorology, where he references combustible bodies. Initially, coal consumption was localized to mining areas due to competition with wood and charcoal, compounded by the logistical challenges of transporting bulk quantities overland. Despite coal's abundance as a fossil energy source in the United States, natural gas has been favoured for power generation due to superior efficiencies, lower capital and operational costs, and reduced emissions, driven by health and safety considerations. The National Energy Policy Development (NEPD) Group underscored the imperative of leveraging technology to achieve the dual objectives of expanding electricity generation while safeguarding the environment. Ultimately, the group advocated for the formulation of a national energy policy aimed at fostering collaboration among businesses, government entities, local communities, and citizens to advance reliable, affordable, and environmentally sustainable energy solutions for the future.

Clements et al. (2008) argue that coal, often perceived as a resource of the past, still holds significant importance that has been underestimated. Despite its historical association, coal remains a primary source of electricity generation in most countries, accounting for a quarter of global primary energy consumption. Notably, the world's largest coal producers—China, the USA, and India - are also the largest consumers. Moreover, smaller coal producers and consumers actively participate in international trade, with seaborne coal trade witnessing significant growth since the 1990s. Recent years have seen a substantial increase in import coal prices, with European importers facing prices exceeding 200 US dollars per ton in September 2008, far above historical averages. This surge has sparked concerns about the potential formation of a supplier cartel, akin to OPEC in the oil market, referred to as "COAL-PEC." Observations indicate a trend towards market concentration in the international coal market, raising suspicions of market power exploitation contributing to price hikes. Factors such as surging demand from China and India, production and shipment capacity constraints, and inadequate investments have been identified as drivers of price escalation. Looking ahead, a tight market and persistently high coal prices are anticipated. However, global coal reserves are projected to last for another 133 years, significantly longer than other fossil fuels like oil (42 years) and gas (60 years). Thus, coal is expected to maintain its crucial role in the global energy mix. Decision-makers in energy, climate, and economic policy are urged to give greater consideration to coal. To align with current climate objectives, efforts should be directed towards making coal-fired electricity generation carbon-free.

Samuel (**2008**) emphasizes that energy serves as a fundamental driver of the global economy, and as such, the world will continue to grapple with pressing energy challenges. Addressing these challenges requires the implementation of a multifaceted solution strategy that leverages both conventional energy sources and emerging alternatives. Fossil fuels, nuclear power, hydrogen, and renewable energy all have pivotal roles to play in mitigating the energy challenges faced by the global economy. Given the complexity of these challenges, collaborative efforts involving researchers, educators, energy think tanks, policymakers, non-governmental organizations, and international bodies are essential to achieve defined objectives and prevent potential crises that could undermine global economic stability. Research initiatives should prioritize the development of clean energy technologies across various energy sources, including fossil fuels, nuclear, and renewables. Moreover, policymakers must be well-informed through comprehensive education regarding long-term energy security to formulate effective policies aimed at addressing future global energy issues. By fostering cooperation and advancing research and policy initiatives, societies can work towards sustainable energy solutions that support economic growth while mitigating environmental impacts.

"The surge in Chinese import demand for coal necessitates thorough analysis, given the distinctive structure of the Chinese coal market, which fosters crucial arbitrage relationships. Changes within China's domestic coal market will wield significant influence over global coal prices and trade patterns, consequently impacting power prices across various regions. Notably, the nature of Chinese demand for international coal differs fundamentally from that of India, another major driver of demand growth in global coal markets. In essence, the intricate politics and economics governing the Chinese coal market have now become inseparable from those shaping the global market." **(Richard Morse & Gang He, 2010).** Coal played a pivotal role in shaping key historical and economic milestones, such as fueling the Industrial Revolution in England during the 18th Century, propelling America's emergence as a major economic power in the late 19th and 20th Centuries, and driving Germany's manufacturing prowess in the early 20th Century. In the present era, coal continues to drive economic growth, particularly in rapidly developing nations like China and India, heralding the onset of 21st-century economic miracles. As globalization unfolds, the international coal market is undergoing a significant transition. Looking ahead, geological realities indicate that countries like China and India, collectively referred to as "Chindia," will increasingly rely on domestic reserves to meet escalating demands, driven by the growing need for electricity and steel production. Consequently, the expanding international coal market will witness a shift towards greater reliance on domestic resources. China, being the world's largest coal arbitrageur, will play a central role in shaping the international coal market. The price of coal on the global stage will become increasingly intertwined with domestic prices in China. This integration poses challenges for importers as higher prices may strain budgets. In response, exporters are unlikely to commit to long-term supply contracts and may opt to reserve resources to ensure consistent supply over the lifespan of coal plants, which can span up to 50 years.

Steven et al. (2010) assert that CO_2 emissions resulting from the combustion of fossil fuels are the primary drivers of global warming. While much scrutiny has been directed towards the direct CO_2 emissions produced by individual countries, relatively little attention has been paid to the emissions associated with the consumption of goods and services within each country. Consumption-based accounting of CO_2 emissions diverges from conventional, production-based inventories due to the inclusion of emissions related to imports and exports of goods and services, which indirectly contribute to CO_2 emissions. Utilizing the latest available data, the study presents a global inventory of consumption-based CO_2 emissions and calculates associated energy and carbon intensities. The findings reveal that in 2004, approximately 23 per cent of global CO_2 emissions, equivalent to 6.2 gigatonnes of CO_2, were traded internationally, predominantly as exports from emerging markets like China to consumers in developed countries. Notably, several affluent nations, including Switzerland, Sweden, Austria, the United Kingdom, and France, imported over 30 per cent of their consumption-based emissions, with net imports exceeding 4 tons of CO_2 per person in 2004. In the United States, net imports accounted for 10.8 per cent of total consumption-based emissions, amounting to 2.4 tons of CO_2 per person in the same year. Conversely, 22.5 per cent of emissions produced in China in 2004 were exported to consumers elsewhere. The analysis underscores the potential for international carbon leakage inherent in consumption-based accounting of CO_2 emissions. By allocating responsibility for emissions among both producers and consumers, there is a possibility of facilitating international consensus on global climate policy, which is currently impeded by concerns surrounding regional and historical disparities in emissions.

According to **Thurber and Morse (2015)**, coal has emerged as the world's fastest-growing energy source for more than a decade. However, it also stands as the largest emitter of CO2 among fossil fuels and contributes significantly to air pollution worldwide. To meet the increasing demand for affordable energy in developing nations while safeguarding the environment, it's essential to gain a profound understanding of the coal market dynamics. This publication provides a thorough examination of the primary producers and consumers shaping the coal industry's trajectory, including key players such as China, India, Indonesia, Australia, and South Africa. By delving into the development of coal sectors in these nations and their interconnectedness through the global coal trade, the authors offer insights into the potential evolution of the global coal market and its economic and environmental implications. This comprehensive analysis serves as a valuable resource for scholars and practitioners engaged in energy economics and policy.

Stala-Szlugaj and Grudziński (2016) highlight coal's significance as one of the primary energy sources globally. Predominantly consumed by the energy sector (with a share ranging from 37-46 per cent between 1990-2014, equivalent to 1.12-2.34 billion toe) and industry (24-27 per cent, accounting for 0.78-1.38 billion toe), coal's distribution across various deposits necessitates extensive transportation over significant distances. Maritime transport dominates the global coal trade, comprising 90-94 per cent of transportation between 2004-2014, while land transport holds a relatively smaller share. The article's objective was to determine the proportion of energy consumed by the transporting train relative to the energy content of the coal being transported on a specific route. Given the significant role of the Russian Federation in coal imports to Poland, the study assumes rail transportation of coal from Kuzbass, Russia's largest coal basin. Calculation results indicate that the energy consumption rate for transporting imported coal falls within the range of 9.22-15.26 per cent. Conversely, deliveries of hard coal from Polish producers to power plants exhibit a lower calculated energy consumption rate, ranging from 0.55-0.58 per cent.

Kimmell and Cleetus (2017) underscored coal's pivotal role in fueling the Industrial Revolution and its continued prominence as a primary energy source worldwide in the 21st century. However, they highlighted the detrimental effects of coal combustion, including significant air and water pollution, along with carbon dioxide emissions, the foremost contributor to climate change. The trajectory of coal's future hinges on the urgency and commitment with which nations address public health concerns and embark on the transition to low-carbon development. Drawing from the experiences of leading economies such as the United States, China, Germany, and India, valuable insights emerge regarding the challenges and opportunities inherent in shifting towards cleaner energy alternatives. This chapter provides a synopsis of the prevailing policy and regulatory landscapes in these countries, with a particular focus on the United States.

Lara (2019) highlights coal's significance as a non-renewable fossil fuel, emphasizing its indispensable role in powering the modern world. Currently, coal ranks as the second-largest primary energy source globally and holds immense importance in electricity generation, as well as the production of steel and metals. With global energy demand steadily rising, particularly in rapidly developing and industrializing economies, concerns regarding energy security are gaining prominence. Coal is perceived as a reliable energy source due to its abundant reserves and comparatively favourable pricing compared to other fossil fuels. However, the combustion of coal in thermal power plants releases greenhouse gas emissions, contributing to climate change. While there is a growing shift towards renewable energy sources to mitigate pollution, coal remains challenging to replace in electricity generation due to its consistent supply and established infrastructure, despite efforts to develop "clean coal energy" technologies. The majority of the world's coal production and consumption are concentrated in Asia, notably in China, the largest consumer and producer of coal-derived energy, driven by its availability and affordability.

Throughout history, the evolution of energy resources has seen a progression from high-carbon to lower-carbon fuels, transitioning from coal to oil to natural gas, and subsequently to non-carbon sources such as hydroelectric, geothermal, wind power, and solar energy. Despite this shift, China remains the largest consumer and producer of coal globally, with coal usage projected to rebound in the near term and peak around 2025, followed by a gradual decline thereafter. In the Asia Pacific region, countries like India, Indonesia, and Southeast Asian nations are expected to witness an increase in coal demand for power generation and industrial purposes over the next decade, according to the International Energy Agency (IEA) in 2020. By the year 2030, global coal demand is forecasted to decrease by approximately 400 million tonnes of coal equivalent compared to 2019 levels. The coal industry is witnessing the emergence of various potential technologies aimed at improving efficiency and reducing environmental impacts. These include hydraulic fracturing to enhance coalbed methane production, CO2 capture, utilization, and sequestration (CCUS) to mitigate CO2 emissions from coal combustion, as well as coal-to-liquid and coal-to-gas fuel conversion technologies to enhance fuel efficiency and reduce CO2 emissions. Furthermore, advancements in digital technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and automation are being utilized to lower operational costs, enhance safety measures, and improve production efficiency in coal operations. Additionally, underground coal gasification (UCG) is being explored as a method to recover coal reserves that are otherwise un-minable. **(Ma et al. 2021)**

III. Coal Production and Consumption in the World and in India

Table 2 - Coal Production in the World and in India

(in Exajoules)

Year	World		India		
	Production	Growth rate (%)	Production	Growth rate (%)	% of Share
2012	162.75		10.68		6.56
2013	165.37	1.47	10.71	5.87	6.48
2014	164.96	0.42	11.28	9.70	6.84
2015	160.37	-2.65	11.77	2.08	7.34
2016	151.58	-2.19	11.89	2.16	7.84
2017	155.01	0.98	11.99	3.21	7.73

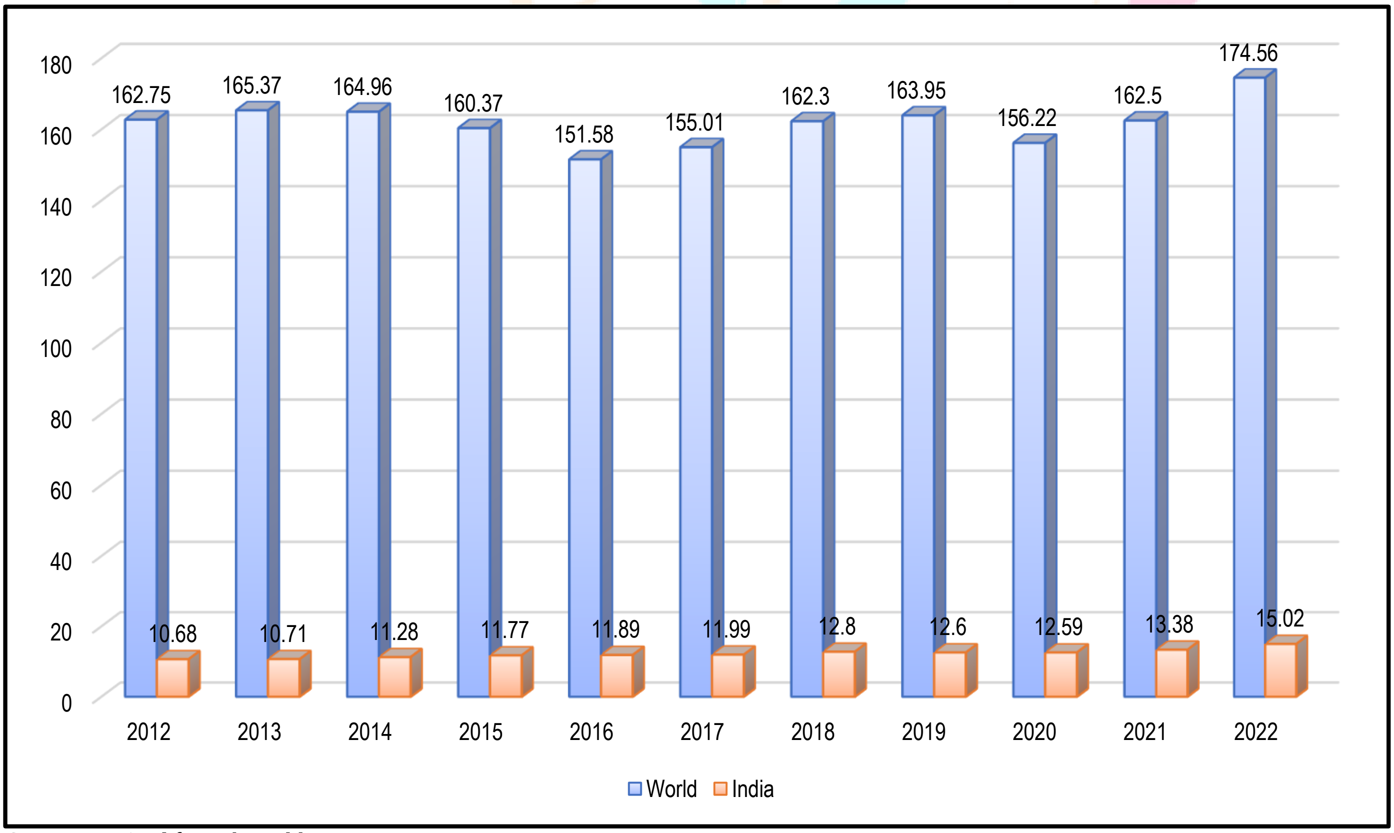
2018	162.30	1.54	12.80	5.16	7.89
2019	163.95	-0.60	12.60	0.17	7.69
2020	156.22	-2.99	12.59	-5.51	8.06
2021	162.50	5.52	13.38	13.73	8.23
2022	174.56	0.65	15.02	4.09	8.60

Source: *Energy Institute (2023).*

Note*: An exajoule (EJ) is a unit of energy equivalent to one quintillion (10^18) joules. It is commonly used in discussions involving global energy consumption and production due to the vast scale of energy involved at the global level. The exajoule provides a convenient way to express large quantities of energy in various contexts, such as in measuring total energy consumption, production, or reserves on a global scale.*

Global coal production has shown fluctuations over the years, from 162.75 exajoules (EJ) in 2012 to 174.56 EJ in 2022. Similarly, India's coal production has generally increased from 6.56 EJ in 2012 to 15.02 EJ in 2022, with occasional fluctuations. The growth rate of global coal production varied annually, ranging from -2.99 per cent in 2020 to 5.52 per cent in 2021. In contrast, India experienced fluctuating growth rates in coal production, with values ranging from -5.51 per cent in 2020 to 13.73 per cent in 2021. India's share of global coal production increased from 4.04 per cent in 2012 to 8.60 per cent in 2022, reflecting its growing significance in the global market. Despite fluctuations, the percentage of India's share in global coal production has shown an overall upward trajectory. Both global and Indian coal production experienced a decline in 2020, likely due to the COVID-19 pandemic and economic slowdowns, with global production decreasing by 2.99 per cent and India's production dropping by 5.51 per cent compared to the previous year. However, in 2021, both global and Indian coal production witnessed a significant recovery, with increases in production levels and growth rates. **(Table 2 & Figure 1)** The data suggests a continued upward trend in Indian coal production, indicating efforts to enhance domestic production capacity. Nonetheless, global production growth rates may continue to fluctuate, influenced by economic conditions, energy policies, and environmental considerations.

Figure 1 - Coal Production in the World and in India



Source: *Derived from the Table 2.*

Table 3 - Coal Consumption in the World and in India

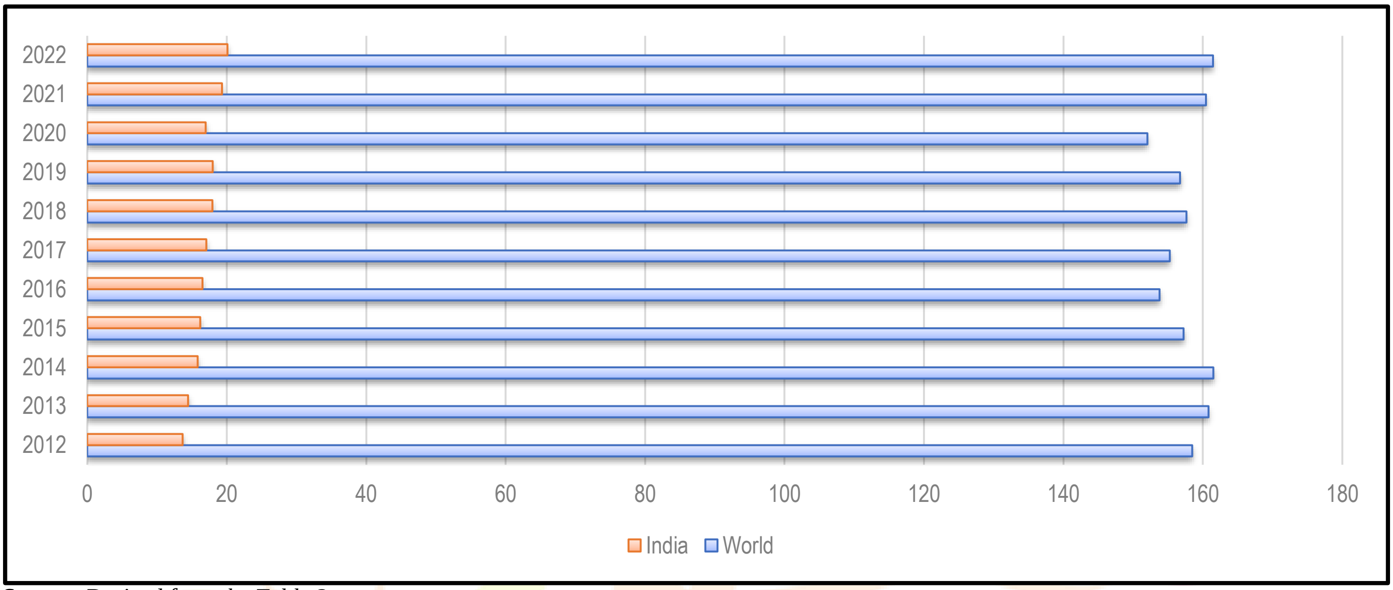
(in Exajoules)

Year	World		India		
	Consumption	Growth rate (%)	Consumption	Growth rate (%)	% of Share
2012	158.48	1.61	13.64	0.28	8.61
2013	160.81	-0.25	14.44	5.32	8.98
2014	161.49	-2.78	15.84	4.34	9.81
2015	157.21	-5.48	16.17	1.02	10.29
2016	153.77	2.26	16.52	0.84	10.74
2017	155.27	4.70	17.05	6.76	10.98
2018	157.66	1.02	17.93	-1.56	11.37
2019	156.72	-4.71	17.96	-0.08	11.46
2020	152.04	4.02	16.97	6.27	11.16
2021	160.43	7.42	19.30	12.26	12.03
2022	161.47	1.61	20.09	0.28	12.44

Source: *Energy Institute (2023). Statistical Review of World Energy, London, UK.*

Global coal production has experienced fluctuations over the years, with a peak of 161.47 exajoules (EJ) in 2022. Meanwhile, India's coal production has shown consistent growth, reaching 20.09 EJ in 2022. Despite occasional declines, both global and Indian coal production have generally increased over the period under review. The growth rates of global coal production have varied annually, ranging from -5.48 per cent in 2015 to 7.42 per cent in 2021. In comparison, India's coal production growth rates have also fluctuated, with values ranging from -1.56 per cent in 2018 to 12.26 per cent in 2021. India's share of global coal production has steadily risen from 8.61 per cent in 2012 to 12.44 per cent in 2022, indicating its growing importance in the global coal market. **(Table 3 and Figure 2)** Overall, the data suggests a positive trend in both global and Indian coal production, with India playing an increasingly significant role in the global coal landscape.

Figure 2 - Coal Consumption in the World and in India



Source*: Derived from the Table 3.*

Table 4 - Coal Trade movements

(In Exajoules)

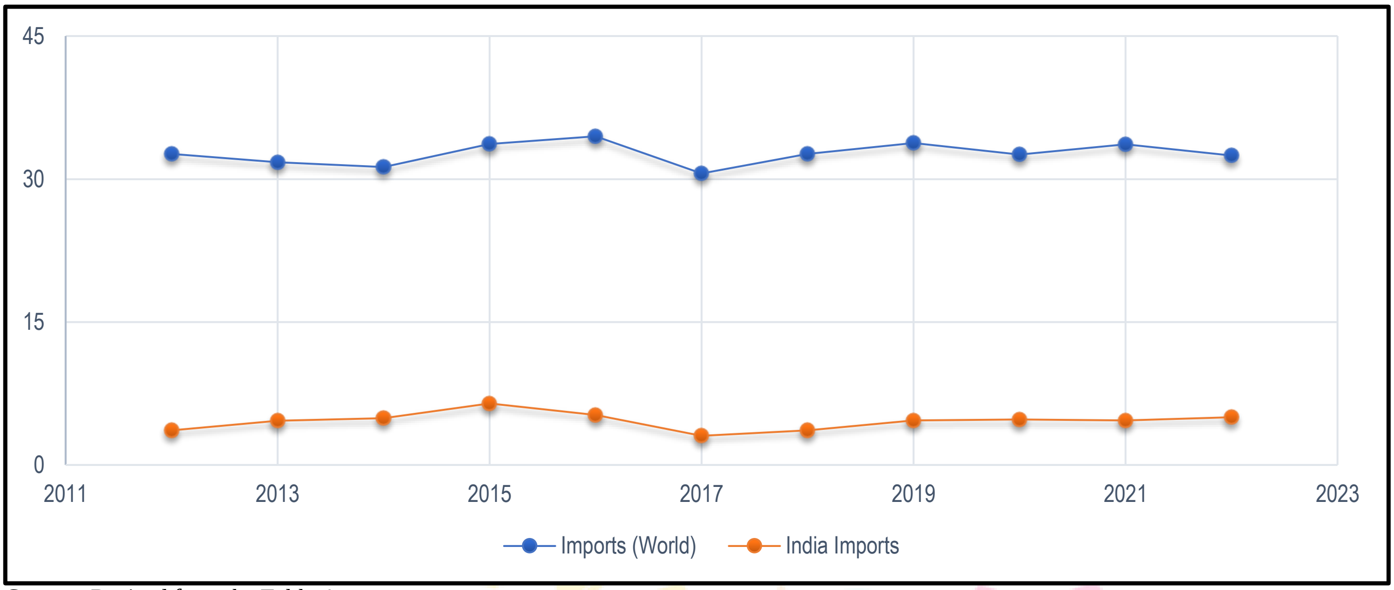
Year	Imports (World)	Growth rate (%)	India Imports	Growth rate (%)	% of Share	Exports (World)	Growth rate (%)
2012	32.65		3.66		11.21	30.61	
2013	31.76	-2.73	4.65	27.05	14.64	32.65	6.66
2014	31.27	-1.54	4.92	5.81	15.73	31.76	-2.73
2015	33.69	7.74	6.46	31.30	19.17	31.27	-1.54
2016	34.50	2.40	5.25	-18.73	15.22	34.50	10.33
2017	30.61	-11.28	3.09	-41.14	10.09	30.61	-11.28
2018	32.65	6.66	3.66	18.45	11.21	32.65	6.66
2019	33.78	3.46	4.70	28.42	13.91	33.78	3.46
2020	32.59	-3.52	4.79	1.91	14.70	32.59	-3.52
2021	33.65	3.25	4.69	-2.09	13.94	33.65	3.25
2022	32.47	-3.51	5.01	6.82	15.43	32.47	-3.51

Source*: Energy Institute (2023). Statistical Review of World Energy, London, UK.*

Table 4 and Figure 3 show fluctuations in both global coal imports and exports over the years. Global coal imports started at 32.65 exajoules (EJ) in 2012, experienced a decline to 30.61 EJ in 2017, and then slightly rose to 32.47 EJ in 2022. Despite occasional dips, the overall trend indicates a moderate increase in global coal imports. India's coal imports displayed varying growth rates throughout the period, ranging from -41.14 per cent in 2017 to 28.42 per cent in 2019. Despite occasional fluctuations, India's coal imports have generally trended upward, reflecting the country's growing energy needs. Meanwhile, global coal exports have seen a gradual decline from 32.65 EJ in 2012 to 15.43 EJ in 2022. The growth rates of global coal exports have fluctuated annually, with significant declines observed in 2017. Overall, the data suggests a dynamic landscape in the global coal trade, with fluctuations in both imports and exports over the years, influenced by various economic and policy factors.

IV. Coal Trade Movements

Figure 3 - Coal Trade movements



Source: *Derived from the Table 4.*

In 2022, international coal trade experienced a decline of almost 4 per cent, marking its lowest level since 2017. Indonesia, Australia, and Russia collectively accounted for slightly over 71 per cent of the total global exports. Notably, Russia witnessed a 12 per cent decrease in its coal exports compared to the previous year. China emerged as the largest importer of coal, with imports reaching nearly 6 exajoules (EJ). Although China's imports from Indonesia declined by 0.5 EJ, there was an increase in imports from Russia and Mongolia by 1.5 EJ and 0.5 EJ, respectively. The Asia Pacific region dominated global coal imports, comprising 74 per cent of the total, while Europe emerged as the second-largest region, witnessing a 10 per cent increase in coal imports compared to 2021.

Table 5 – Top Coal Importing and Exporting Countries in the World

S.No.	Country	US$ (Billion)	Share % in Total Import	Country	US$ (Billion)	Share % in Total Export
1.	Japan	59.7	20.8	Australia	83.30	35.0
2.	India	49.0	17.1	Indonesia	46.70	19.6
3.	China	30.3	10.6	Russia	42.80	18.0
4.	South Korea	28.2	9.8	United States	17.30	7.3
5.	Taiwan	16.4	5.7	South Africa	13.00	5.5
6.	Germany	12.9	4.5	Canada	10.80	4.5
7.	Türkiye	8.2	2.8	Mongolia	6.50	2.7
8.	Malaysia	7.0	2.4	Netherlands	2.20	0.9
9.	Philippines	6.0	2.1	Mozambique	2.00	0.9
10.	Poland	5.7	2.0	Poland	1.60	0.7
11.	Brazil	5.5	1.9	Colombia	1.30	0.6
12.	Vietnam	5.0	1.7	China	1.20	0.5
13.	Italy	4.2	1.5	Kazakhstan	0.95	0.4
14.	Indonesia	3.6	1.3	Philippines	0.88	0.4
15.	Chile	3.0	1.1	Belgium	0.76	0.3

Source: *https://www.worldstopexports.com/*

Table 5 shows Australia leads the pack as the largest exporter of coal, accounting for a substantial 35 per cent share of the total export market. With an export value of US$ 83.3 billion, Australia's coal industry plays a pivotal role in meeting global demand. Indonesia follows closely behind, boasting a significant share of 19.6 per cent in the export market, with exports valued at US$ 46.7 billion. Russia also holds a prominent position, contributing 18 per cent of the total export market, with coal exports amounting to US$ 42.8 billion. The United States and South Africa round out the top five exporting nations, with export shares of 7.3 per cent and 5.5 per cent, respectively. On the import side, Japan emerges as the leading importer of coal, with a substantial 20.8 per cent share of the total import market. Importing coal worth US$ 59.7 billion, Japan heavily relies on coal to meet its energy needs. India closely follows Japan, commanding a 17.1 per cent share in the import market, with coal imports valued at US$ 49.0 billion. China, the world's largest coal consumer, maintains a significant presence in the import market, with a share of 10.6 per cent and imports totalling US$ 30.3 billion. South Korea and Taiwan also play crucial roles as importers, with shares of 9.8 per cent and 5.7 per cent, respectively, in the global import market. Overall, the export and import dynamics of coal underscore the interdependence among nations in meeting energy demands and driving economic growth. The contributions of key exporting and importing countries highlight the intricate balance and cooperation required to sustain the global coal trade network.

Box 1
Coal in Capsule form

In 2022, coal prices soared to unprecedented levels, with European prices averaging $294/tonne and the Japan CIF spot price averaging $225/tonne, marking increases of 145 per cent and 45 per cent respectively compared to 2021. Despite this, coal consumption continued its upward trend, rising by 0.6 per cent in 2021 to reach 161 EJ, the highest level since 2014. This growth was primarily fuelled by a 1 per cent increase in demand from China and a 4 per cent increase from India. Together, these countries contributed 1.7 EJ to global consumption, offsetting declines in other regions by 0.6 EJ. Notably, coal consumption in North America and Europe declined by 6.8 per cent and 3.1 per cent respectively. Additionally, in 2022, OECD consumption remained around 10 per cent lower than its pre-COVID 2019 levels, while non-OECD coal consumption increased by over 6 per cent. Global coal production surged by over 7 per cent compared to 2021, reaching a record high of 175 EJ, with China, India, and Indonesia accounting for over 95 per cent of this increase.

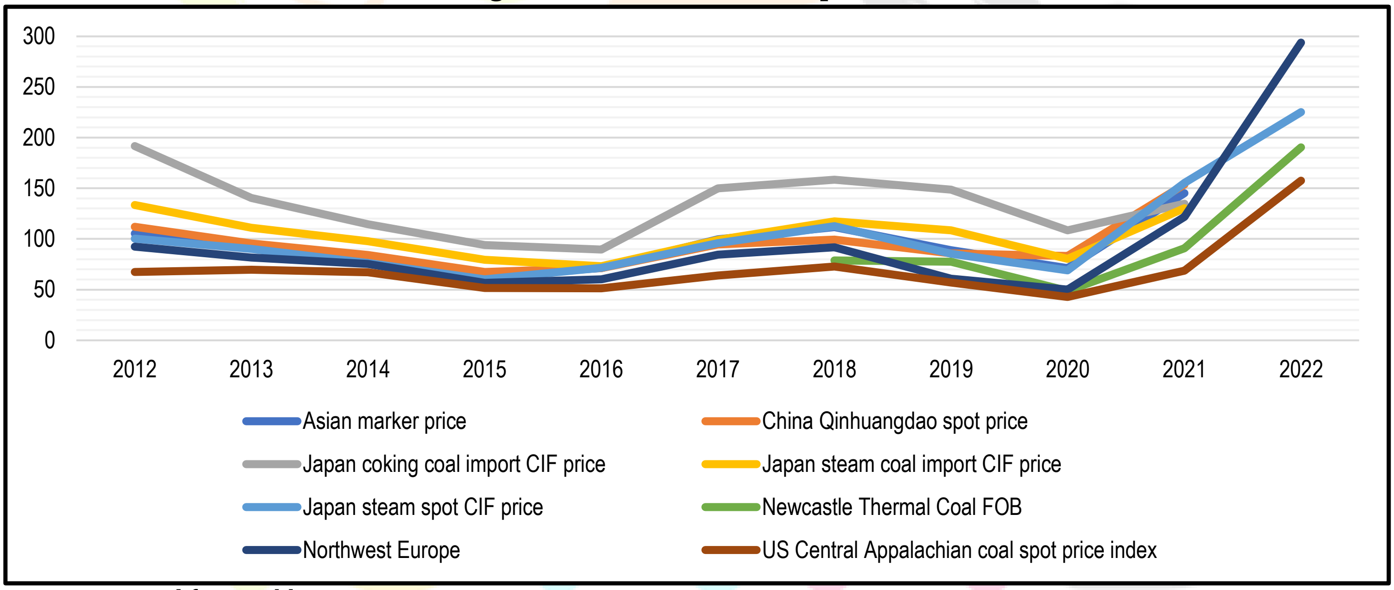
V. Coal current Price

Table 6 - Coal current US$ per tonne

Production zone	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Asian marker price	105.50	90.90	77.89	63.52	71.12	99.58	111.69	88.98	71.33	145.16	
China Qinhuangdao spot price	111.89	95.42	84.12	67.53	71.35	94.72	99.45	85.89	83.10	153.55	
Japan coking coal import CIF price	191.46	140.45	114.41	93.85	89.40	150.00	158.49	148.52	108.41	134.86	
Japan steam coal import CIF price	133.61	111.16	97.65	79.47	72.97	99.16	117.39	108.58	80.50	130.37	
Japan steam spot CIF price	100.30	90.07	76.13	60.10	71.66	96.02	112.73	85.48	69.01	155.41	225.27
Newcastle Thermal Coal FOB							78.67	77.59	48.81	90.82	190.35
Northwest Europe	92.50	81.69	75.38	56.79	60.09	84.51	91.83	60.86	50.16	121.70	293.63
US Central Appalachian coal spot price index	67.28	69.72	67.08	51.57	51.45	63.83	72.84	57.16	42.77	68.54	157.57

Source: *https://ourworldindata.org/grapher/coal-prices?tab=table&time=2012..2021*

Figure 4 - Coal current US$ per tonne



Source: Derived from Table 6.

From **Table 6 and Figure 4** The prices of coal across different production zones have exhibited significant fluctuations over the years. Generally, there is a noticeable downward trend in prices from 2012 to 2016, followed by a period of fluctuation and then a substantial increase in prices from 2020 onwards. This overall trend suggests volatility in the coal market influenced by various factors such as supply-demand dynamics, geopolitical factors, and environmental regulations. Prices vary significantly across different production zones, reflecting variations in production costs, transportation expenses, and market demand. For example, the Asian marker price and the China Qinhuangdao spot price generally follow similar trends, indicating a strong correlation between coal prices in these regions. In contrast, prices in regions like Northwest Europe and the US Central Appalachian coal spot price index show different patterns, likely influenced by regional supply-demand dynamics and market conditions. Prices for specific types of coal, such as coking coal and steam coal, exhibit different trends, reflecting variations in demand and usage patterns across industries. The Newcastle Thermal Coal FOB price, representing coal exported from Australia, shows a significant increase from 2018 to 2022, suggesting changes in global demand or supply dynamics specific to this region. The fluctuations and upward trend in coal prices from 2020 onwards may be attributed to various factors, including increased demand from emerging economies, supply disruptions, and shifts in energy policies. Environmental concerns, regulatory changes, and the transition to cleaner energy sources could also influence coal prices, impacting the long-term outlook for the coal industry. These price fluctuations have implications for various stakeholders in the coal industry, including producers, consumers, investors, and policymakers. Producers may benefit from periods of high prices but face challenges during price downturns, necessitating strategic planning and risk management. Consumers, particularly industries reliant on coal as an energy source, may experience cost fluctuations, impacting their operational expenses and profitability. Policymakers and investors need to consider the broader market trends and regulatory developments when making decisions related to energy policies, investments, and sustainability goals. In conclusion, the data highlights the complex and dynamic nature of the global coal market, characterized by price volatility and influenced by a myriad of factors. Understanding these trends and their implications is crucial for stakeholders seeking to navigate the challenges and opportunities in the coal industry.

VI. Negative Externalities of Coal

Coal, in essence, embodies a duality akin to Dr. Jekyll and Mr. Hyde: its inherent physicochemical properties render it a financially appealing fuel source while simultaneously exacting a "significant toll on human health and the environment" (**United Nations**, 2020a). Throughout each stage of the coal "life cycle," spanning from extraction to eventual waste disposal, both direct and indirect repercussions are felt across air, water, soil, ecosystems, as well as animal and human health (**Dai et al., 2017**). The paramount environmental concerns, highlighted by the United Nations in their 2019 Global Environment Outlook Report (**UNEP**, 2019c), revolve around climate change and biodiversity. Joyce Msuya, Acting Executive Director of the UN Environment Programme, emphasized, "The scientific evidence is unequivocal. The well-being and economic success of humanity are intricately linked to the condition of our environment" (**UN News**, **2019**). One of the environmental impacts associated with coal mining and usage is visual blight, characterized by the occasional transient or lasting devastation of the environment required by coal extraction and related operations.

Additional environmental concerns linked to coal mining comprise land subsidence, contaminated streams, and acid mine drainage. Conversely, the commercial combustion of coal introduces a distinct array of environmental challenges, such as acid rain (one of the few problems, like acid rain, that have been substantially mitigated), the discharge of particulates (such as fly ash), and the release of greenhouse gases, notably carbon dioxide. The extraction, storage, transportation, and utilization of coal give rise to fugitive dust (**Miller, 2011b**), which poses a substantial threat to human and animal health, as well as the environment. Dust generated during extraction presents an occupational hazard for miners and has been correlated with pulmonary diseases such as coal workers' pneumoconiosis (CWP, "black lung disease"), chronic obstructive pulmonary disease (COPD), and silicosis (**NIOSH, 2011**). Emissions from coal-fired power plants, particularly those lacking the latest pollution control technology, may contain hazardous air pollutants, exposing individuals to mercury, sulfur dioxide, nitrogen oxides, particulate matter, toxic heavy metals (e.g., As, Pb, Cd, Se), radioactive elements (e.g., uranium, radium, thorium), carbon monoxide, nitrogen oxides (NOx), and volatile organic compounds (**Finkelman, 1994**; **Union of Concerned Scientists, 2008**). According to **George D. Thurston**, a professor of population health and environmental medicine at New York University, "Our findings suggest that weight for weight, particles from coal combustion contribute approximately five times as much to the risk of heart disease mortality as the average air pollution particle in the United States" (**Fears, 2015**). Aside from cardiovascular impacts, exposure to coal dust and emissions has been associated with respiratory effects and diminished lung function, heightened vulnerability to viral and bacterial infections, low birth weight in newborns, increased infant mortality, neurological effects, and reduced life expectancy (**Lockwood et al., 2009**; **Burt et al., 2013**). In the United States, as of 2010, adverse health effects linked to emissions from coal plants, which contribute to almost 50 per cent of electricity generation (**Earth Talk, 2015**), impact nearly 2 million individuals annually. The total monetized worth of these health impacts surpasses $100 billion per year.

The 'Coal Kills' report (**Goenka and Guttikunda, 2013**) projected that in India, coal is associated with 80,000 to 115,000 premature deaths each year. In Europe, coal is responsible for approximately 23,300 fatalities annually, with the economic toll of health impacts from coal combustion estimated at around US$70 billion per year, resulting in the loss of 250,600 life years (**EndCoal, 2020**). Occupational health consequences encompass pulmonary ailments such as chronic bronchitis, chronic obstructive pulmonary disease (COPD), coal workers' pneumoconiosis (CWP, "black lung disease"), emphysema, progressive massive fibrosis (PMF), and silicosis (**Markandya and Wilkinson, 2007**; **NIOSH, 2011**). Coal possesses a propensity to undergo combustion, leading to uncontrolled fires upon exposure to air. These coal fires are pervasive worldwide, posing hazards to both human and animal populations, as well as the environment. Furthermore, they inflict economic hardships by depleting a valuable resource, ravaging the local environment, and contaminating streams and air (**Finkelman, 2004**). Residents residing within one mile of an active coal fire were 98 per cent more likely to report a variety of health concerns compared to those living five miles away from the fire. Globally, an estimated 3 billion individuals rely on unprocessed solid fuels like coal, kerosene, and/or biomass (such as wood, animal dung, or crop waste) for cooking (**WHO, 2018**), often utilizing indoor open fires or inefficient, basic stoves. Inadequate combustion of solid fuels, compounded by inadequate ventilation, exposes individuals, typically women, children, and the elderly, to heightened levels of potentially harmful air pollutants within the household (e.g., black carbon, carbon monoxide, complex organic compounds, metals, and particulate matter; e.g., **Finkelman et al., 1999**; **Gordon et al., 2014**; **Balmes, 2019**), and also contributes to ambient air pollution once released outside the home. Household cooking with coal has been linked to significant health issues, including mental illness (**Braithwaite et al., 2019**), acute respiratory problems in children, lower respiratory infections, lung cancer, chronic obstructive pulmonary disease (COPD) in women, and cataracts. The leaching of organic compounds from low-rank coals such as lignite, sub-bituminous coal, and brown coal into aquifers utilized for drinking water could potentially contribute to a fatal kidney disease. The global energy sector is the largest contributor to greenhouse gas emissions, accounting for 73 per cent worldwide (**Ge and Friedrick, 2020**). Within this sector, coal-fired power generation remains the primary emitter, responsible for 30 per cent of all energy-related carbon dioxide emissions (**IEA, 2019b**), and is identified as the leading cause of global temperature rise (**Rice, 2019**).

Climate change impacts, as documented by **Borenstein (2019)** and **WMO (World Meteorological Organization), 2020**, encompass progressively severe weather events, leading to floods and storms, heat and cold stress, droughts, melting ice sheets, and increased UV radiation (**BMJ, 2015**; **WMO, 2020**). These ecological disturbances will affect human health by exacerbating vector-, food-, and water-borne diseases and deteriorating air quality (**BMJ, 2015**; **Silva et al., 2017**). Numerous phases within the coal lifecycle contribute to land-use change and resource damage (**Dai et al., 2017**; **Giam et al., 2018**). These impacts, both direct and indirect, primarily involve the alteration of landscapes, including agricultural and forested areas, as well as the degradation of the physical environment and the destruction of wildlife habitats and ecosystems. Additionally, they result in damage to recreational lands, land subsidence, increased methane emissions (which contribute to climate change), sedimentation, and erosion (**Epstein et al., 2011**; **Miller, 2011a**). Underground mining activities have the potential to trigger collapses and facilitate land subsidence, fundamentally reshaping the topography. Surface mining operations significantly modify the land surface through the removal of rock and soil, potentially leading to erosion and mass wasting. Every aspect of the global water cycle is influenced by coal extraction, processing, transportation, utilization, and disposal, with impacts extending spatially and temporally. Mining activities directly affect the quality (i.e., contamination), quantity, and availability of surface and groundwater. Underground extraction activities may alter groundwater levels and flow directions, while surface mining often degrades surface waters through stream runoff. These consequences can lead to the depletion of water resources over time and result in permanent modifications to local and/or regional recharge zones. Acid mine discharges (AMD) originating from both active and abandoned underground mines persist as the most significant water quality and watershed degradation concern in coal mining regions. Structural failures associated with the short- and long-term storage of coal byproducts during processing (such as coal slurry) and utilization (such as the storage of coal ash) can lead to water supply contamination (as seen in the Kingston Fossil Plant coal ash spill; **Bourne, 2019**), pose physical hazards to animal and human life (as demonstrated in the 1966 Aberfan Disaster; **Solly, 2019**), and increase the risk of adverse health outcomes due to exposure to toxic compounds. The substantial use of water imposes a significant strain on local resources, including regional aquifers (**Averyt et al., 2011**). Land clearance, along with associated mining activities and construction, disrupts and displaces wildlife populations as habitats undergo alteration and destruction. Coal-fired power plants represent a significant source of anthropogenic mercury emissions; once deposited onto terrestrial and aquatic surfaces, mercury undergoes transformation and transportation within the environment. Methylmercury (MeHg), the predominant organic form, is a recognized environmental toxicant due to its propensity for bioaccumulation in organisms (**Clarkson, 2002**; **Sunderland et al., 2018**) and biomagnification through successive trophic levels in food webs, resulting in elevated concentrations in higher trophic-level organisms.

VII. Conclusion

Coal mining and consumption significantly contribute to carbon dioxide (CO2) emissions, exacerbating climate change. These emissions arise from various stages, including the combustion of diesel and gasoline in mining machinery, the use of explosives releasing CO2, and the energy-intensive processes involved in mining operations. Additionally, the transportation of coal emits CO2, and methane, a potent greenhouse gas, is released during mining. When coal is burned for electricity or industrial purposes, it emits CO2, varying based on coal type. Industrial processes such as steel and cement production also release CO2 from coal combustion and chemical reactions. Residential and commercial coal use, particularly in developing regions, further adds to CO2 emissions. To mitigate these emissions, advancements in mining and combustion efficiency are necessary, alongside transitioning to renewable energy sources like wind and solar power. Carbon capture and storage technologies can also help capture emissions from coal-fired plants. Addressing CO2 emissions from coal mining and consumption is vital for combating climate change and fostering a sustainable energy future, requiring technological innovation, policy interventions, and consumer behaviour shifts towards cleaner energy options.

References

[1] Averyt, K., Fisher, J., Huber-Lee, A., Lewis, A., Macknick, J., Madden, N., Rogers, J., and Tellinghuisen, S. (2011). Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource. A Report of the Energy and Water in a Warming World initiative. Union of Concerned Scientists, Cambridge, MA, p. 62. Retrieved from https://www. ucsusa.org/sites/default/files/attach/2014/08/ew3-freshwater-use-by-us-power-plants.pdf

[2] Balmes, J. R. (2019). Household air pollution from domestic combustion of solid fuels and health. Journal of Allergy and Clinical Immunology, 143(6), 1979e1987.

[3] BMJ (2015). Paris Climate Change Talks: What Doctors Need to Know. The BMJ, Feature Briefing. Retrieved from https://www.bmj.com/content/351/bmj.h6316/infographic. (Accessed August 23, 2020).

[4] Borenstein, S. (2019). Warming toll: 1 degree hotter, trillions of tons of ice gone. APNews.com, The Associated Press, New York, NY. Retrieved from https://apnews.com/e5687657f8544c30b42f0c8641a4f7db. (Accessed September 14, 2020).

[6] Bourne Jr., J. K. (2019, February 19). Coal's Other Dark Side: Toxic Ash that Can Poison Water and People. National Geographic Society, Washington, DC. Retrieved from https://www.nationalgeographic.com/environment/2019/02/coal-otherdark-side-toxic-ash/#close. (Accessed August 30, 2020).

[7] Braithwaite, I., Zhang, S., Kirkbride, J. B., Osborn, D. P. J., and Hayes, J. F. (2019). Air pollution (particulate matter) exposure and associations with depression, anxiety, bipolar, psychosis and suicide risk: A systematic review and meta-analysis. Environmental Health Perspectives, 127(12), 126002.

[8] Bruce, G., and Miller. (2005). Past, Present, and Future Role of Coal. 29-76. doi: 10.1016/B978-012497451-7/50002-4

[9] Burt, E., Orris, P., and Buchanan, S. (2013). Scientific Evidence of Health Effects from Coal Use in Energy Generation [Report]. University of Illinois at Chicago School of Public Health, Chicago, IL, p. 18. Retrieved from https://noharm-uscanada.org/sites/default/files/documents-files/828/Health_Effects_Coal_Use_Energy_Generation.pdf.

[10] Clarkson, T. W. (2002). The three modern faces of mercury. Environmental Health Perspectives, 110, 11e23.

[11] Clemens, Haftendorn, and Christian von Hirschhausen. (2008). Moving towards a "COAL-PEC"?

[12] Dai, W., Dong, J., Yan, W., and Xu, J. (2017). Study on each phase characteristics of the whole coal life cycle and their ecological risk assessment: A case of coal in China. Environmental Science and Pollution Control Series, 24, 1296e1305.

[13] EarthTalk. (2015, February 17). How Coal Kills. Scientific American, Sustainability (Section).
[14] Springer Nature, New York, NY. Retrieved from https://www.scientificamerican.com/article/how-coal-kills/. (Accessed September 21, 2020).
[15] EndCoal. (2020). Health. EndCoal.org. Retrieved from https://endcoal.org/health/. (Accessed May 29, 2020).
[16] Energy Institute (2023). Statistical Review of World Energy, London, UK.
[17] Epstein, P. R., Buonocore, J. J., Eckerle, K., Hendryx, M., Stout III, B. M., Heinberg, R., Clapp, R. W., May, B., Reinhart, N. L., Ahern, M. M., Doshi, S. K., and Glustrom, L. (2011). Full cost accounting for the life cycle of coal. Annals of the New York Academy of Sciences, 1219(1), 73e98.
[18] Fears, D. (2015, December 2). Coal is king among pollution that causes heart disease, study says. The Washington Post, Health and Science Section. WP Company LLC, Washington, DC. Retrieved from https://www.washingtonpost.com/national/health-science/coal-is-king-among-pollution-that-causes-heartdisease-study-says/2015/12/01/3fb88194-9840-11e5-8917-653b65c809eb_story.html. (Accessed June 1, 2020).
[19] Finkelman, R. (2004). Potential human health impacts of burning coal beds and waste banks. International Journal of Coal Geology, 59(1e2), 19e24.
[20] Finkelman, R. B. (1994). Trace elements in coal: A USGS perspective of the Clean Air Act. ACS Preprints, 39(2), 519e523.
[21] Finkelman, R. B., Belkin, H. E., and Zheng, B. (1999). Health impacts of domestic coal use in China. Proceedings of the National Academy of Sciences of the United States of America, 96(7), 3427e3431.
[22] Fouquet, R., and Pearson, P. J. G. (1998). A thousand years of energy use in the United Kingdom. Energy Journal, 19(4), 1e41.
[23] Freese, B. (2003). Coal: A Human History. Perseus Books Group, Cambridge, MA, p. 308.
[24] Ge, M., and Friedrich, J. (2020). 4 charts explain greenhouse gas emissions by countries and sectors. World Resources Institute, Blog. Retrieved from https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-countrysector. (Accessed August 23, 2020).
[25] Giam, X., Olden, J. D., and Simberloff, D. (2018). Impact of coal mining on stream biodiversity in the US and its regulatory implications. Nature Sustainability, 1(4), 176e183.
[26] Goenka, D., and Guttikunda, S. (2013). Coal Kills - an Assessment of Death and Disease Caused by India's Dirtiest Energy Source. Urban Emissions, India, p. 36. Retrieved from https://wayback.archive-it.org/9650/20200401013954/http://p3-raw.greenpeace.org/india/Global/india/report/Coal_Kills.pdf.
[27] Gordon, S. B., Bruce, N. G., Grigg, J., Hibberd, P. L., Kurmi, O. P., Lam, K. H., Mortimer, K., Asante, K. P., Balakrishnan, K., Balmes, J., Bar-Zeev, N., Bates, M. N., Breysse, P. N., Buist, S., Chen, Z., Havens, D., Jack, D., Jindal, S., Kan, H., Mehta, S., Moschovis, P., Naeher, L., Patel, A., Perez-Padilla, R., Pope, D., Rylance, J., Semple, S., and Martin II, W. J. (2014). Respiratory risks from household air pollution in low and middle income countries. The Lancet Respiratory Medicine, 2(10), 823e860.
[28] IEA [International Energy Agency]. (2019). Global Energy and CO2 Status Report 2019: The Latest Trends in Energy and Emissions in 2018. International Energy Agency, Paris, France, p. 29. Retrieved from https://www.iea.org/reports/global-energy-co2-statusreport-2019. (Accessed August 20, 2020)
[29] James, R., McFarland, Howard, J., Herzog, and Henry, D., Jacoby. (2005). The future of coal consumption in a carbon constrained world. doi: 10.1016/B978-008044704-9/50180-4
[30] K., Stala-Szlugaj., and Zbigniew, Grudziński. (2016). Energy efficiency and steam coal transport over long distances. doi: 10.1051/E3SCONF/20161000089
[31] Ken Kimmell, and Rachel Cleetus. (2017). The State of Coal Regulation Around the World: Insights from the United States, China, Germany, and India. 147-172. doi: 10.1039/9781788010115-00147
[32] Kennedy, C. (2020). The energy embodied in the first and second industrial revolutions. Journal of Industrial Ecology, 24(4), 887e898.
[33] Lara, Kerep. (2019). Tržište ugljena u svijetu.
[34] Lockwood, A. H., Welker-Hood, K., Rauch, M., and Gottlieb, B. (2009). Coal's Assault on Human Health: A Report from Physicians for Social Responsibility. Physicians for Social Responsibility, Washington, DC, p. 64. Retrieved from https://www.psr.org/wpcontent/uploads/2018/05/coals-assault-on-human-health.pdf.
[35] Ma, H., Chen, S., Xue, D., Chen, Y., Chen, Z. (2021). Outlook for the coal industry and new coal production technologies. Advances in Geo-Energy Research, 5(2), 119-120. doi: 10.46690/ager.2021.02.01
[36] Mackay, C. (1859). Old king coal [poem]. American Farmer's Magazine, 12(17), 292.
[37] Mark, C., Thurber, Richard K., Morse. (2015). The Global Coal Market. Research Papers in Economics.
[38] Markandya, A., Wilkinson, P. (2007). Electricity generation and health. Lancet, 370(9591), 979e990.
[39] Mathis, C. F. (2018). King coal rules: Accepting or refusing coal dependency in Victorian Britain. Revue Française De Civilisation Britannique (French Journal of British Studies), 23(3), 17.
[40] Miller, B. G. (2011a). Coal as fuel: Past, present, and future (chapter 1). In B. G. Miller (Ed.), Clean Coal Engineering Technology (pp. 1e51). Butterworth-Heinemann, Boston, MA.
[41] Miller, B. G. (2011b). The effect of coal usage on human health and the environment (chapter 4). In B. G. Miller (Ed.), Clean Coal Engineering Technology (pp. 85e132). Butterworth-Heinemann, Boston, MA.
[42] Morse, R., and He, G. (August 2010). The World's Greatest Coal Arbitrage: China's Coal Import Behavior and Implications for the Global Coal Market. Stanford University, Stanford, California, USA. Available from: http://pesd.stanford.edu/publications/the_worlds_greatest_coal_arbitrage_chinas_coal_import_behavior_and_implications_for_the_global_coal_market/
[43] NIOSH [National Institute for Occupational Safety and Health]. (2011). Coal Mine Dust Exposures and Associated Health Outcomes: A Review of Information Published since 1995. Current Intelligence Bulletin, vol. 64. Department of Health and Human Services, Washington, DC, p. 56. Available at: https://www.cdc.gov/niosh/docs/2011-172/pdfs/2011-172.pdf.
[44] Orwell, G. (1937). Down the mine (Part 1, chapter 2). In G. Orwell (Ed.), The Road to Wigan Pier. Project Gutenberg of Australia, pp. 18e31. https://libcom.org/files/wiganpier.pdf
[45] Rice, D. (2019, March 26). Coal is the Main Offender for Global Warming, and yet the World is Using it More than ever. USA Today, Nation (Section). Gannett Company, Tysons Corner, VA. Retrieved from https://www.usatoday.com/story/news/nation/2019/03/26/climate-change-coal-still-king-global-carbonemissions-soar/3276401002/. (Accessed August 25, 2020).
[46] Samuel, Frimpong. (2008). Global Energy Security: The Case for a Multifaceted Solution Strategy. Journal of Energy Engineering-asce. doi: 10.1061/(ASCE)0733-9402(2008)134:4(109)

[47] Silva, R. A., West, J. J., Lamarque, J.-F., Shindell, D. T., Collins, W. J., Faluvegi, G., Folberth, G. A., Horowitz, L. W., Nagashima, T., Naik, V., Rumbold, S. T., Sudo, K., Takemura, T., Bergmann, D., Cameron-Smith, P., Doherty, R. M., Josse, B., MacKenzie, I. A., Stevenson, D. S., Zeng, G. (2017). Future global mortality from changes in air pollution attributable to climate change. Nature Climate Change, 7(9), 647e651.
[48] Solly, M. (2019). The True Story of the Aberfan Disaster. SmithsonianMag.com, Washington, DC. Retrieved from https://www.smithsonianmag.com/history/true-story-aberfan-disaster-featured-crown180973565/. (Accessed August 30, 2020)
[49] Steven, J., Davis., Ken, Caldeira. (2010). Consumption-based accounting of CO2 emissions. Proceedings of the National Academy of Sciences of the United States of America. doi: 10.1073/PNAS.0906974107
[50] Sunderland, E. M., Miling, L., Bullard, K. (2018). Decadal changes in the edible supply of seafood and methylmercury exposure in the United States. Environmental Health Perspectives, 126(1), 1e6.
[51] UN. (2020a). Climate change [website]. Available at: https://www.un.org/en/sections/issues-depth/climate-change/. (Accessed August 16, 2020).
[52] UNEP (2019). Global Environment Outlook e GEO-6: Healthy Planet, Healthy People. Cambridge University Press, Cambridge, United Kingdom, p. 745. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/27539/GEO6_2019.pdf?sequence=1&isAllowed=y.
[53] Union of Concerned Scientists. (2008). Coal and Air Pollution. Union of Concerned Scientists, Reports & Multimedia, Cambridge, MA. Article dated 28 July 2008 (updated 19 December 2017). Retrieved from https://www.ucsusa.org/resources/coal-and-airpollution. Accessed 18 2020.
[54] WHO (2018). Household Air Pollution and Health (Fact Sheet No. 292). World Health Organization, Geneva, Switzerland. Retrieved from https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. (Accessed September 14, 2020).
[55] WMO (2020). WMO Statement on the State of the Global Climate in 2019. World Meteorological Organization, Geneva, Switzerland, p. 44 (WMO-No. 1248). Retrieved from https://library.wmo.int/doc_num.php?explnum_id=10211.